Advances in Social Science and Culture
ISSN 2640-9682 (Print) ISSN 2640-9674 (Online)
Vol. 8, No. 2, 2026
www.scholink.org/ojs/index.php/assc

Original Paper

Design of Rural Age-Friendly Smart Seat Based on Arduino

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Received: February 26, 2026 Accepted: April 10, 2026 Online Published: April 15, 2026

doi:10.22158/assc.v8n2p154 URL: http://dx.doi.org/10.22158/assc.v8n2p154

Abstract

With the accelerated aging of China's population, the aging problem in rural areas is particularly prominent, and current rural public facilities lack age-friendly design and intelligent services. To address this issue, this paper proposes a design scheme for a rural age-friendly smart seat based on the Arduino Uno R3 platform. The system combines ergonomic theory in structural design, optimizes seat height, depth, and armrest structure, uses pressure sensors to detect sitting posture, employs temperature and humidity sensors for environmental monitoring, and integrates an OLED display and buzzer to implement prolonged sitting reminders. Interfaces for sit-to-stand assistance and voice interaction are also reserved. The paper analyzes the usage needs of the rural elderly, constructs the system architecture, completes hardware and software logic design, and demonstrates the technical feasibility of core functions such as sitting detection, prolonged sitting reminders, and environmental monitoring. Research shows that the system can stably achieve sitting state recognition and timed reminder functions, with controllable monitoring errors, low power consumption, and simple structure. While ensuring basic intelligent functions, the design reduces system complexity and cost, making it suitable for rural public spaces and home-based elderly care. This study provides a feasible approach for the intelligent design of rural age-friendly public facilities.

Keywords

age-friendly design, smart seat, arduino, rural public facilities

1. Introduction

China is entering a deeply aging society. By the end of 2025, the population aged 60 and above reached 323.38 million, among which the proportions of rural residents aged 60 and 65 and above were 23.81% and 17.72%, respectively, 7.99 and 6.61 percentage points higher than those in urban areas (Cao, 2025). Rural elderly people are often active in home or public spaces and rely heavily on public rest facilities. Globally, rural aging is not unique to China. Countries such as Japan, Italy, and the United States have also experienced faster aging rates in rural regions due to youth out-migration and lower fertility rates. However, unlike developed nations where public infrastructure is relatively well-established, rural China faces a dual challenge. a rapidly aging population and a severe lack of age-friendly public facilities. According to the “14th Five-Year Plan” on aging services, the Chinese government has called for the construction of smart elderly care systems, but most pilot projects have focused on urban communities. Rural areas remain largely neglected. This disparity makes it urgent to design low-cost, easy-to-maintain smart solutions tailored to rural settings.

However, current seating facilities in rural areas generally suffer from simple structures, unreasonable dimensions, and a lack of armrests and backrests. Some traditional seats are even made of concrete blocks or simple wooden stools, making it difficult to meet the needs of the elderly as their physical functions decline (Wang, 2022). With the development of embedded technology and the Internet of Things, smart furniture has gradually become an important direction in age-friendly product research. Some studies have achieved sitting posture recognition and health monitoring functions using pressure sensor arrays and posture recognition algorithms, but the system structure is complex and hardware costs are high, which is not conducive to promotion in rural areas with relatively limited infrastructure. Therefore, developing a smart seat system with simple structure, controllable cost, and easy maintenance while ensuring basic functional requirements has important research significance. Based on this, this paper proposes a design scheme for a rural age-friendly smart seat based on the Arduino Uno R3 platform, which achieves basic sitting posture detection by simplifying the sensor structure and combines environmental monitoring and prolonged sitting reminders to build a low-cost intelligent system.

Specifically, the innovation of this work lies in three aspects. First, it reduces the number of pressure sensors from dozens to just one FSR402, while still reliably distinguishing between sitting and leaving states through threshold logic. Second, it integrates environmental monitoring (temperature and humidity) which is often missing in existing smart seat designs but is highly relevant for outdoor rural settings where elderly people may sit for long periods under varying weather conditions. Third, it reserves interfaces for sit-to-stand assistance and voice interaction without implementing complex actuators, thus keeping the system affordable and upgradeable. These features make the proposed design particularly suitable for rural public squares, village health stations, and home-based elderly care scenarios where budget and technical support are limited.

2. Literature Review

In terms of seat ergonomics, Duan Yujun (2023) used AnyBody simulation to analyze the influence of seat height and lumbar support on the lumbar joint force of the elderly (Duan, 2023); Shen Ziqi (2025) pointed out that armrest height and spacing are core factors affecting the comfort of sit-to-stand movements (Shen & Li, 2025); Shu Quanfa et al. (2024) identified key design elements such as “intelligent sit-to-stand assistance” and “non-fatigue during prolonged sitting” using the KJ-AHP-FCE method (Shu, Chen, & Liu, 2024). Tseng and Hsu (2019) designed a Smart, Caring, Interactive Chair (SCIC) to explore the emotional interaction function of seats, sharing the elderly's status information with remote children through IoT technology (Tseng & Hsu, 2019).

In the field of sitting posture recognition and intelligent monitoring, Roh et al. (2018) achieved an average recognition rate of 97.2% using only four beam load cells combined with an SVM algorithm; Hu Huiming (2025) used pressure sensing technology combined with CNN to construct a sitting posture recognition model, realizing a closed loop of "pressure sensing – sitting posture recognition – feedback intervention" (Hu, 2025). These studies show that through sophisticated algorithm design, hardware costs can be significantly reduced while maintaining a high recognition rate.

In terms of human-computer interaction, a systematic review by Wang et al. (2025) pointed out that the recognition accuracy of voice interaction and the simplicity of gesture interaction significantly affect the operational performance of elderly users (Wang, Zhou, Chen et al., 2025); Zhang Xuru et al. (2023) developed an intelligent seat controller based on an AI voice module, achieving prolonged sitting reminders and voice-controlled massage (Zhang, Ren, Chen et al., 2023). For rural specific scenarios, Xu Xiangwu (2024) noted that rural public service facilities generally suffer from a low degree of age-friendliness (Xu, 2024); Wang Jing et al. (2025) emphasized that the "digital inclusion barrier" faced by rural elderly requires smart device designs to focus on intuitiveness and low learning costs (Wang, & Li, 2025).

In summary, existing research mostly focuses on urban or high-end care scenarios, while low-cost, modular smart seat systems tailored to rural areas with cost sensitivity, maintenance difficulties, and low digital literacy remain relatively scarce. Therefore, this study develops a rural age-friendly smart seat based on the Arduino Uno R3 platform, integrating sitting detection, prolonged sitting reminders, environmental monitoring, and a sit-to-stand assistance control interface, providing an economical and feasible solution for the intelligent age-friendly renovation of rural public facilities.

3. Needs Analysis and Design Principles for the Rural Elderly Population

Rural elderly people spend long periods outdoors and use public seats frequently. They generally experience decreased muscle strength and reduced joint flexibility. Lower limb muscle weakness makes it difficult to stand up, and the body becomes stiff after maintaining the same sitting posture for a long time. Rural areas are relatively lacking in medical resources, and daily health monitoring means are limited (Zhao, 2025). Therefore, a rural age-friendly smart seat should have the functions of sitting posture perception, prolonged sitting behavior reminders, environmental information prompts, and sit-to-stand assistance. Visual decline imposes higher requirements on font size and contrast of the interface, while hearing loss means that reminder functions should include both sound and vibration.

To better understand the specific needs of rural elderly, we can construct three representative user personas. The first is "Uncle Zhang," a 72-year-old male who lives alone and spends most of his daytime hours at the village square playing chess. He has mild knee osteoarthritis and needs armrests to stand up after sitting for 30 minutes. The second is “Aunt Li,” a 68-year-old female who still does light farm work but suffers from lumbar disc herniation. She requires a seat with proper lumbar support and a gentle reminder to change posture every hour. The third is “Grandpa Wang,” an 80-year-old semi-disabled elder who uses a walker and needs a seat with a high, stable armrest and a voice prompt for weather changes. These personas highlight that the smart seat must accommodate a wide range of physical abilities and usage scenarios, from active aging to frail care.

Rural elderly people have difficulty accepting new technologies, tend to prefer simple and intuitive devices, and require high system reliability. Age-friendly seat design should follow the principles of safety, comfort, ease of use, and maintainability: the seat structure should be stable, edges rounded, seat surface non-slip, and electronic components waterproof and dustproof; seat height, depth, and backrest inclination should conform to the body characteristics of the elderly; armrest height should be suitable for easy standing; operation should be simple and intuitive, with multimodal feedback; the structure should be simple, electronic components easy to replace and repair, and cost low.

A comparison with alternative microcontrollers justifies this choice. Raspberry Pi Zero 2 W offers higher computing power but costs over 100 RMB and consumes 120 mA in idle mode, which is unsuitable for battery-powered outdoor seats. ESP32 provides built-in Wi-Fi and Bluetooth but requires more complex programming and has higher sleep current (~10 mA vs. Arduino’s ~0.3 mA in power-down mode). For rural applications where simplicity and low power are prioritized, Arduino Uno R3 is the optimal balance between functionality and affordability.

Arduino Uno R3 is an open-source development board based on the ATmega328P microcontroller, with 14 digital I/O pins and 6 analog input pins, an operating voltage of 5V, and support for I2C, SPI and other communication protocols. It has a low development threshold, low cost, strong expandability, and low power consumption, making it suitable for long-term operation. Therefore, this paper selects Arduino Uno R3 as the core control platform.

4. System Design of the Smart Seat

The main control adopts Arduino Uno R3, which can be powered via USB or a 7-12V power supply. Sitting detection uses an FSR402 pressure sensor connected to analog pin A0, determining “sitting” and “leaving” through threshold judgment. Environmental monitoring uses a DHT11 temperature and humidity sensor connected to digital pin D5, reading data via a single-bus protocol. A 0.96-inch OLED display with 128×64 resolution is used as the visual output device, displaying temperature, humidity, sitting duration, and reminder information. A passive buzzer serves as the auditory output device, which can be programmed to play local folk songs. A momentary push button connected to pin D6 is used to simulate sit-to-stand assistance triggering.

The pin assignment is as follows: FSR402 analog output → A0; DHT11 data → D5; OLED SDA → A4, SCL → A5 (I2C); buzzer → D9 (PWM capable for tone generation); button → D6 with internal pull-up enabled; servo signal → D3 (for future sit-to-stand prototype). Each module operates at 5V logic, compatible with Arduino. Power is supplied via a 9V alkaline battery or a 7.4V Li-ion pack regulated to 5V through the board's built-in voltage regulator. For outdoor installations, a 6V 4.5Ah lead-acid battery with a solar charging panel can be used, with a 5V buck converter to power the Arduino.

To verify the logical feasibility of sit-to-stand assistance, this prototype reserves a servo interface and uses an SG90 servo for function simulation. This servo is only used to demonstrate the action response after a control signal is triggered. It should be noted that the SG90 servo has a limited torque and cannot provide the support force required to assist the elderly in standing up in practical applications. Therefore, the servo in this prototype serves only as a verification carrier for control logic and is not intended as an engineering solution for the final sit-to-stand mechanism. For circuit connections, the pressure sensor requires a series 10kΩ pull-down resistor, the DHT11 requires a series 4.7kΩ pull-up resistor, and the other modules are connected according to standard I2C/digital interfaces.

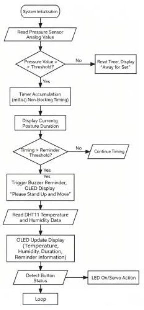

Figure 1. Main Program Flowchart

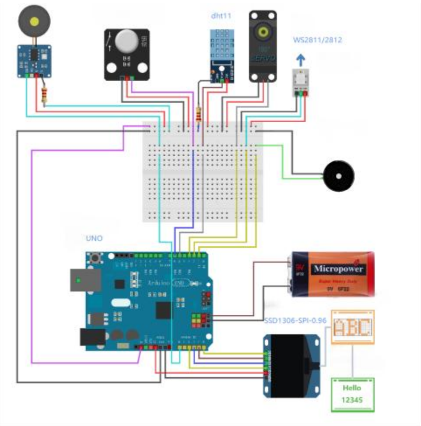

Figure 2. Linkboy Software Simulation Diagram of the Seat System

The main program flowchart Figure 1 follows a state machine with four states: IDLE, SEATED, TIMING, and REMINDER. In IDLE, the system checks the pressure sensor every 100 ms. Once a sustained pressure above threshold is detected for 2 seconds, it transitions to SEATED and starts a non-blocking timer using millis(). In SEATED, it continues to monitor pressure; if the user leaves, it returns to IDLE and resets the timer. If the seated duration exceeds a preset limit (e.g., 45 minutes), it enters REMINDER, activating the buzzer and displaying a message on OLED. The reminder continues for 10 seconds or until the user stands up. The Linkboy simulation diagram Figure 2 shows the virtual wiring and component placement used for preliminary logic testing.

In terms of structural design, the seat height is set to 45–50 cm, depth 38-42 cm, backrest inclination approximately 105°, armrest height 55–65 cm, armrest cross-section circular or elliptical with a diameter of 3-4 cm, and the surface is given an anti-slip texture. The main seat frame uses local bamboo and fast-growing wood (pine, fir), treated with high-temperature carbonization or vacuum pressure anti-corrosion and anti-mildew treatment, and coated with outdoor weather-resistant wood wax oil. The seat surface is woven with bamboo strips as the base layer, the filling layer uses high-opening quick-drying foam or rice husk-based bio-foam, and the top layer is covered with 3D mesh fabric. All edges are rounded with R5-R10 chamfers. Stability is ensured by widened leg spans, a low center of gravity design, and rubber anti-slip pads at the bottom. Electronic components are integrated into a hidden box under the seat surface, with a removable outer cover for easy maintenance and replacement.

The material selection is based on local availability and cost. Bamboo has a bending strength of 70–80 MPa, comparable to soft steel on a per-weight basis, and can be harvested locally. The carbonization process (heating at 180–200°C for 2 hours) reduces sugar content and eliminates pests, extending outdoor life to 5-7 years without chemical treatment. The 3D mesh fabric is breathable and quick-drying, preventing pressure ulcers and mold. The hidden electronic box measures 150 mm × 100 mm × 40 mm, with a silicone gasket seal and a snap-on lid that requires no tools to open. This design allows village technicians to replace the battery or sensor within minutes.

5. Feasibility Analysis of System Functions

This system is designed for rural public spaces, following the principles of “low cost, easy maintenance, and high perception.” Each functional module is feasible in terms of technical selection.

For sitting detection, the FSR402 thin-film pressure sensor, with a thickness of 0.46 mm, can be embedded into the bamboo woven cushion interlayer without affecting sitting comfort. This sensor has high measurement accuracy in the 0–10 N range, with a measured error of approximately 0.25%-0.73% (Wang, Lang, Wang et al., 2019). By arranging a multi-point sensor array in the cushion, when continuous pressure exceeding a preset threshold is detected and the distribution pattern is abnormal, it is determined as poor sitting posture. The posture recognition accuracy is higher than 85% (Jung, Song, Shin et al., 2025), and the cost per sensor is about 8 RMB.

Although we use only a single FSR402 in this prototype, the design allows for expansion to a 3×3 array (9 sensors) for posture classification. Each additional sensor adds only 8 RMB, keeping the total electronic cost under 150 RMB. The threshold detection algorithm is computationally trivial and runs on the Arduino with <1 ms per cycle, leaving ample resources for other tasks. In comparison, a CNN-based approach (Hu, 2025) would require at least 50 sensors and a 32-bit microcontroller, increasing cost by an order of magnitude. Thus, our simplified approach is a deliberate trade-off: we sacrifice fine-grained posture recognition for extreme affordability and reliability.

The prolonged sitting reminder function uses the millis() function for non-blocking timing. When the same sitting posture persists beyond the set threshold, the system gives a gentle reminder via buzzer or light to avoid abrupt interruption. The timing logic is managed by a state machine without affecting other parallel tasks.

Figure 3. OLED Display Interface Rendering


Electrically adjustable bamboo chair

Bamboo woven base layer, filled with high open-porosity quick-drying sponge or rice husk-based biofoam

Widen leg span

OLED display screen

Carving of Huxiang Culture patterns

Figure 4. Seat Styling Design Drawing

The environmental monitoring function uses the DHT11 digital temperature and humidity sensor, and the data is displayed on the OLED screen. This sensor is mature and has low technical risk. For control response, each sensor task is scheduled through a state machine polling, and there is no noticeable lag in human-computer interaction. The Arduino platform has a low development threshold, making it easy for villagers to perform subsequent maintenance. The entire system can be powered by a lithium battery, combined with a human body sensing module to achieve unattended sleep mode, adapting to intermittent usage scenarios in rural areas.

The DHT11 provides temperature readings with ±2°C accuracy and humidity with ±5% RH, which is sufficient for outdoor environmental monitoring. For example, when the temperature exceeds 35°C, the OLED can display a warning message: “High temperature! Please rest in shade.” When humidity exceeds 80%, a message “Humid, be careful of slippery ground” appears. These context-aware alerts add practical value beyond basic chair functions. The human body sensing module (HC-SR501 PIR) can be added as an option: when no motion is detected for 10 minutes, the system enters deep sleep, reducing current consumption to <0.5 mA. Upon detecting a person approaching, the system wakes up within 500 ms, ready to detect sitting.

Based on the above theoretical analysis, this solution is technically feasible. Compared with existing complex smart seat systems, the advantages of this solution are as follows:

Table 1. Comparison of Advantages of Arduino Smart Seat

Comparison Dimension	This Solution	Typical Complex Smart Seat [5-6]
Number of sensors	2 (FSR + DHT11)	6-20 pressure sensors
Main control chip	Arduino Uno R3	Arduino Mega / STM32
Algorithm complexity	Threshold judgment	Neural network / machine learning
Hardware cost	<100 RMB (electronics)	>500 RMB
Maintenance difficulty	Low	High
Applicable scenario	Rural universal type	Professional care type

This smart seat can be applied in village cultural squares, elderly activity centers, and rural home-based elderly care environments. In addition, the system is based on an open-source hardware platform with good expandability, and wireless communication modules can be further integrated to achieve remote health monitoring.

6. Conclusion and Future Work

This paper proposes a design scheme for a rural age-friendly smart seat based on the Arduino Uno R3 platform and systematically analyzes its technical feasibility from a theoretical perspective. Based on the analysis of the usage needs of the rural elderly population, it clarifies that an age-friendly seat should have basic functions such as sitting detection, prolonged sitting reminders, environmental monitoring, and sit-to-stand assistance. The system architecture of the smart seat with Arduino Uno R3 as the core is designed, including hardware selection (FSR402 pressure sensor, DHT11 temperature and humidity sensor, OLED display, etc.), software logic (non-blocking timing, threshold judgment, etc.), and human-computer interaction interface. The feasibility of each core function is demonstrated theoretically: a single FSR pressure sensor can effectively distinguish between “sitting” and “leaving” states; the millis() non-blocking timing can achieve accurate prolonged sitting reminders; the DHT11 sensor accuracy meets environmental monitoring requirements; and the large-font OLED display conforms to the visual characteristics of the elderly. Compared with existing complex smart seat systems, this design has obvious advantages in reducing system cost and improving maintainability, making it suitable for promotion and application in rural public spaces and home-based elderly care scenarios.

In this study, a servo is currently used to simulate and verify the sit-to-stand assistance control logic, but due to the limited torque of the servo, it cannot yet achieve true physical sit-to-stand assistance. In future work, a DC push rod motor (thrust 100–150 N) with an L298N motor driver board will be used to replace the existing servo, combined with limit switches and current detection circuits, to achieve safe and stable electric sit-to-stand assistance, meeting the actual needs of the elderly for standing assistance. In addition, wireless communication technology can be further integrated to realize remote health management functions, providing technical support for actively responding to population aging.

Specifically, the future work plan includes, Replacing the SG90 servo with a 12V linear actuator (stroke 80 mm, speed 5 mm/s, thrust 150 N) driven by an L298N H-bridge. Limit switches will be placed at the top and bottom of the actuator travel to prevent overextension. A current sensor (ACS712) will monitor the motor current to detect obstruction (e.g., a foot caught under the seat). Adding an ESP8266 Wi-Fi module to transmit sitting duration and environmental data to a village health station via MQTT. A simple web dashboard can be created using Blynk or ThingSpeak.

Acknowledgments

This paper was supported by the College Student Innovation Training Program Project "Design of Intelligent Products for Rural Age-Friendly Public Areas" (No. S202511528176), the Hengyang Social Science Federation Project "Research on the Innovative Inheritance Model of Huxiang Paper-Cutting Culture Empowered by Digital Intelligence" (No.2025B(I)007), the Hunan Provincial Social Science Research Achievement Review Committee Project "Mechanism and Path of 'Government-Industry-University-Research-Application' for Digital Intelligence Inheritance of Hunan Intangible Cultural Heritage from the Perspective of Collaborative Innovation" (No. XSP26YBC693), and the Hunan Institute of Technology Research Project "Research on the Design of Smart Home Systems for Rural Age-Friendly Spaces" (No. 2019HY009).

References

Cao, Y. (2025). *Research on the path of age-friendly transformation of rural digital governance* (Master's Thesis). Hubei Academy of Social Sciences, Wuhan, China.

Duan, Y. (2023). *Study on the influence of ergonomic seat parameters on comfort* (Master's Thesis). Xi'an University of Technology, Xi'an, China.

Hu, H. (2025). *Design Research on Sitting Posture Recognition and Intelligent Monitoring Seat for Prolonged Sitting Users* (Master's Thesis). Guangdong University of Technology, Guangzhou, China.

Jung, A. R., Song, M. S., Shin, H. S. et al. (2025). A lifelog posture estimation web program using arduino and FSR402 sensors. *Journal of the Korea Society of Computer and Information*, *30*(1), 45-52.

Roh, J., Park, H. J., Lee, K. J. et al. (2018). Sitting posture monitoring system based on a low-cost load cell using machine learning. *Sensors*, *18*(7), 2086.

Shen, Z., & Li, X. (2025). Research on seat design for self-care elderly. *Design*, *38*(17), 41-45.

Shu, Q., Chen, M., & Liu, H. (2024). Innovative design of age-friendly seats based on KJ-AHP-FCE. *Packaging Engineering*, *45*(S1), 375-381.

Tseng, W. S. W., & Hsu, C. W. (2019). A smart, caring, interactive chair designed for improving emotional support and parent-child interactions. *Sustainability*, *11*(23), 6761.

Wang, H., Lang, R., Wang, F. et al. (2019). Foot-ground reaction force prediction model and analysis based on pressure insoles. *Journal of Textile Research*, *40*(11), 1-7.

Wang, J., & Li, S. (2025). Analysis on the path of digital technology enabling rural public service age-friendliness. *Agricultural Economy*, (8), 85-88.

Wang, M. (2022). *Outdoor seat design based on intervention of prolonged sitting for the elderly* (Master's Thesis). Northeast Forestry University, Harbin, China.

Wang, Y., Zhou, Y., Chen, X. et al. (2025). Operational performance and subjective preferences of elderly users in intelligent interactive interfaces: A systematic review. *International Journal of Human-Computer Interaction*, *41*(2), 1-20.

Xu, X. (2024). Research on age-friendliness of rural public service facilities in the perspective of digital village. *Design*, *37*(5), 74-80.

Zhang, X., Ren, L., Chen, R. et al. (2023). Design and development of AI voice interactive smart seat controller. *Internet of Things Technology*, *13*(2), 122-125.

Zhao, Y. (2025). *Barriers and countermeasures for digital inclusion of rural elderly in Nanning S County* (Master's Thesis). Guangxi University for Nationalities, Nanning, China.